INCREASE IN FOSSIL FUEL UTILIZATION IN THE TWENTY-FIRST CENTURY: ENVIRONMENTAL IMPACT AND LOWER CARBON ALTERNATIVES

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INTRODUCTION

Interest in the utilization of fossil fuels has greatly increased during the past few years; not because of the benefits to be derived from the energy produced, but rather because of the concerns related to the continued increase of emissions of greenhouse gases and their potential relationship to global climate change. It is generally recognized that there are trade-offs between the benefits to society that accrue from economic development and the possible ecological and environmental degradation brought about by that development. Within the next half century, the world's population will increase and, in order to serve the needs of growth and economic development, energy production will necessarily increase by a significant amount. The means by which the world will simultaneously resolve the dilemma posed by increased population, demand for energy, and concern for the environment will greatly impact the quality of life for most of the people on Earth.

POPULATION

The most recent biennial revision of population estimates and projections of the United Nations Population Division (1998) shows the rate of increase in the world population to be slowing. The current world population is 5.9 billion persons and the medium fertility projection, which the U.N. authors consider most likely, is for the world population to reach 8.9 billion in 2050. That is somewhat lower than previous projections. This slowing of the rate of population increase is the result of two factors; one of which most people would consider positive and the other negative. The global fertility rates have decreased in the past 50 years from five births per woman to the current level of 2.7 births. Although, the decline in fertility is worldwide, it is most pronounced in the developed countries, many of which have birth rates below that necessary to maintain a stable population.

The second factor affecting the rate of population growth is the devastation brought about by the epidemic of HIV/AIDS in much of the world, especially Africa. According to the United Nations Population Division report (1998), the 29 hardest hit African countries have average life expectancies that are seven years less than they would have been in the absence of AIDS.

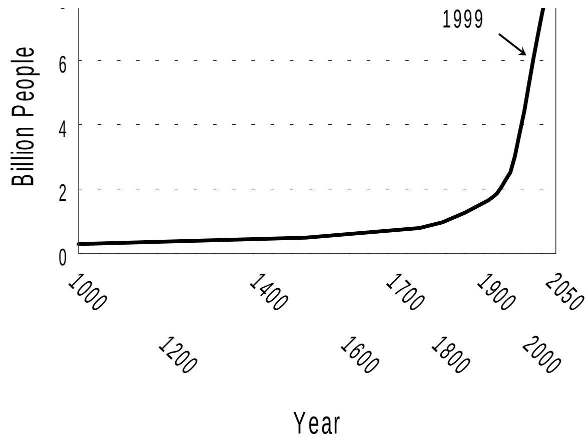

Figure 1. World population, 1000 - 2050, United Nations 1998 Revision of the World Population E Estimates and Projections.

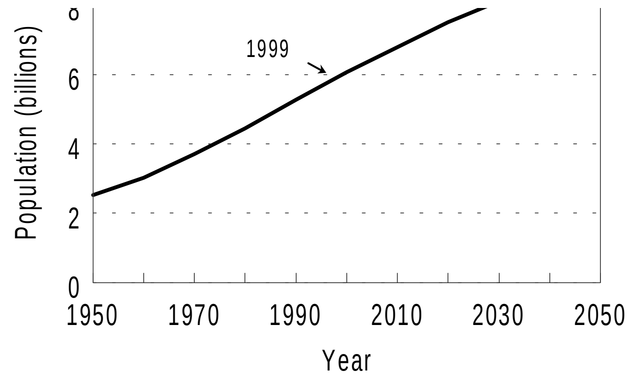

Figure 2. World Population, 1950 - 2050, United Nations 1998 Revision of the World Population Estimates and Projections

The pattern of growth in the world population from the year 1000 AD projected to 2050 (figure 1) is what one might expect from a living organism, and the population total is increased by an additional billion people every 12 to 13 years. The future does not appear as desperate if only one segment of that curve, from 1950 to 2050, is considered (figure 2). The world population will increase 50 percent over the next 50 years, primarily in Africa and Asia, accompanied, in these regions, by a significant trend to increased urbanization. The underdeveloped countries have a rate of urbanization that is 3.5 times that in developed regions (World Resources Institute, 1996, p. 1).

POPULATION AND ENERGY CONSUMPTION

Historically, a growth in world population has been accompanied by an increase in demand for energy. From 1970 to 1990 the total world commercial energy consumption increased 59 percent while the world population was increasing 43 percent (figure 3). Commercial energy includes energy

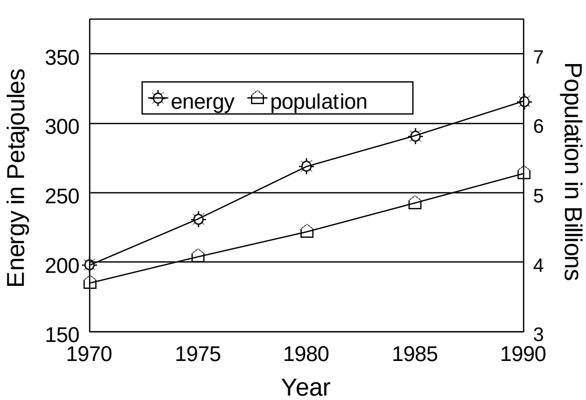

Figure 3. Growth in world population and world energy consumption, 1970 - 1990. Data from World Resources Institute, 1996, World Resources 1996-97, files HD 16101 and 21201.

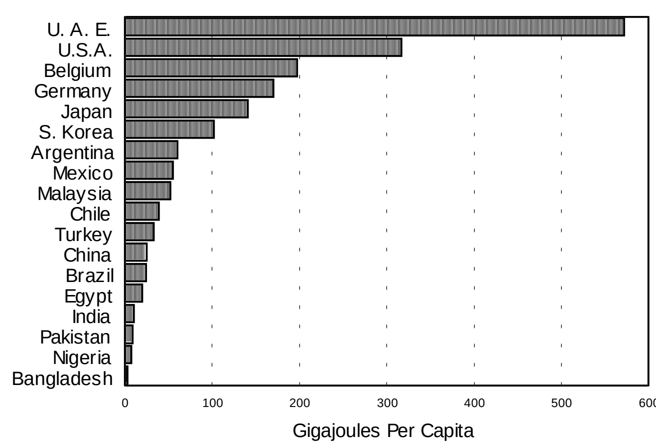

Figure 4. Commercial energy Consumption, 1993, for selected countries. Units are in gigajoules per capita (1 gigajoule equals 947.800 Btu) . Source: World Resources Institute, 1996,

from solid, liquid, and gaseous fuels and primary electricity (hydroelectricity, nuclear, solar, wind, etc.), but does not include traditional fuels such as wood, charcoal, and animal wastes.

Population, alone, is not an accurate predictor of energy consumption. That is because there is a wide range in energy consumption per capita between the developed, developing, and undeveloped countries (figure 4). On a worldwide basis, the mean annual per capita energy consumption is 59 gigajoules (1 gigajoule = 947,800 Btu). However, the median per capita value is much lower than 59 gigajoules because the developed nations consume energy at a rate that is one or two orders of magnitude greater than that of the developing countries. For example, Mexico, Malaysia, and Argentina have per capita energy consumption near the mean value (59, 52 and 60 gigajoules, respectively) and the per capita consumption in the United States and Canada is 317-319 gigajoules. At the lower end of the scale are Nigeria (7 gigajoules), Bangladesh (3 gigajoules), and Haiti (1 gigajoule)(World Resources Institute, 1996 data table 12.2).

If we were to project energy consumption in the year 2050 based upon population alone it would increase 50 percent, the same amount as the population increase. However, the population growth will be mainly in countries in which the energy use is below the mean for the world. The 10 countries projected to have the largest national populations in 2050 are, in descending order, India, China, United States, Pakistan, Indonesia, Brazil, Nigeria, Bangladesh, Ethiopia, and the Democratic Republic of the Congo (United Nations, 1998). If they were to keep their per capita energy consumption constant during the next 50 years, they would only utilize 140 percent of their current energy in 2050. If the United States were to continue using energy at the current rate and the other nine countries were to increase their rate to that of Spain (85 gigajoules per capita), then the ten largest countries in 2050 would increase their energy consumption to 395 percent of that used today. Spain was chosen because it is at the lower end of energy consumption per capita of the countries in Europe.

India is projected to have the largest national population in 2050 with more than 1.5 billion people and China will be nearly as large (United Nations, 1998). These two countries currently utilize coal as the primary source of commercial energy. India uses five times as much energy from coal as from liquid fuels and China four times as much (World Resources Institute, 1996, data table 12.1). It is reasonable to assume that these two countries will continue using their indigenous coal resources as their primary fuel for electricity generation as their populations increase and, hopefully, their economies grow.

The Gross Domestic Product (GDP) is an economic indicator that correlates with many parameters considered to be associated with standard of living or quality of life. Darmstadter and Lile (1997) analyzed data from 114 countries in the world and found that there was a good positive correlation with adult literacy rate, life expectancy, and percentage of the population with access to sanitation. They concluded that GDP is a useful tool for evaluating key contributors to standard of living. Economists have adopted a form of GDP that allows for comparison of a currency's purchasing power within its own country. This is GDP based on "Purchasing Power Parity" or PPP and it represents the amount of a common "market basket" of goods each currency can purchase locally. It is that form of GDP (per capita) used in this paper.

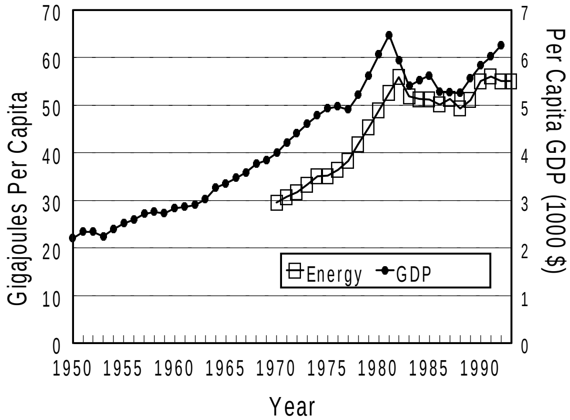

Figure 5. Per capita GDP and energy consumption per capita in Mexico, 1950 - 1993. Data from World Resources Institute, 1996, World Resources 1996-97, data files EI 15124 and EM 21202

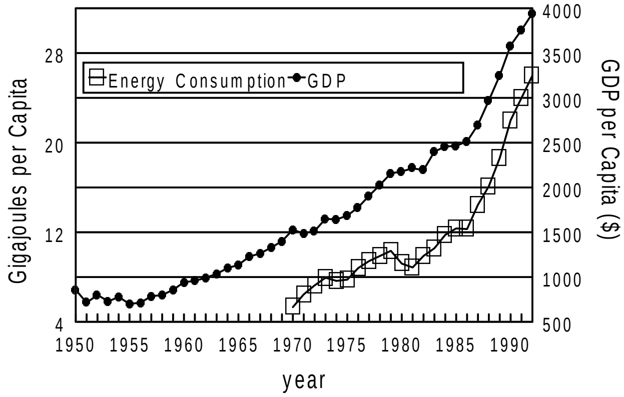

Figure 6. Per capita GDP and energy consumption per capita in Thailand, 1950 - 1993. Data from World Resources Institute, 1996, World Resources 1996-97, data files EI 15124 and EM 21202

Examples of parallel growth of GDP andenergconsumption in two countries experiencing rapid economic development are shown in figure 5 and figure 6. From 1970 to 1992, the per capita energy consumption in Mexico increased 86 percent and the GDP increased 57 percent. During the same time period, a per capita increase in GDP in Thailand of 160 percent was accompanied by an increase in energy consumption of 387 percent. Because of the correlation between economic development, expressed as GDP, and energy consumption, it is reasonable to use GDP as a proxy for energy usage. There have been a few cases in which the rate of increase in GDP in a country has been greater than the rate of increase in energy consumption and therefore the proxy would not be valid. That has occurred only in highly developed countries with high GDP. One example is the response of the United States economy to increased energy prices of the 1970's (figure 7) and the continuing conservation efforts in what had been a profligate energy consuming economy.

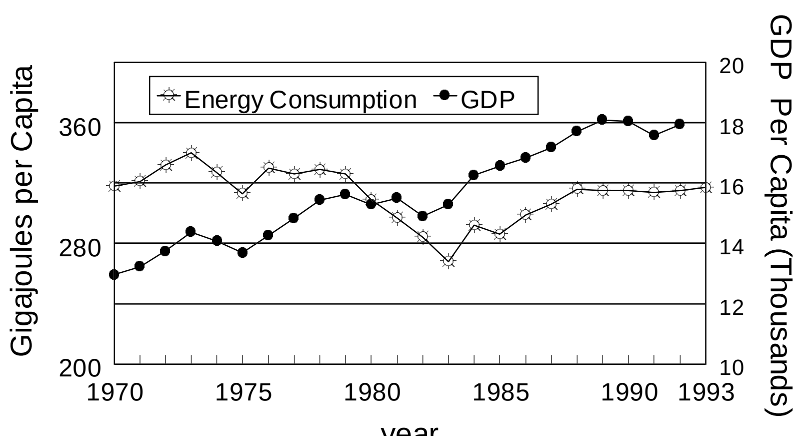

Figure 7. Per capita GDP and energy consumption per capita in the United States, 1970 - 1993. Data from World Resources Institute, 1996, World Resources 1996-97, data files EI 15124 and EM 21202

ECONOMIC GROWTH AND THE ENVIRONMENT - KUZNETS CURVES

The environmental Kuznets curve, named for Nobel laureate economist, Simon S. Kuznets, plots the relationships between environmental quality factors and per capita income. Seldon and Song (1994) looked at sulfur dioxide, suspended particulate matter, carbon monoxide and nitrogen oxides in a multi-national study. Grossman (1995) plotted Kuznets curves for sulfur dioxide and suspended

particulate matter on a multi-national basis, and also analyzed suspended particulate matter , airborne

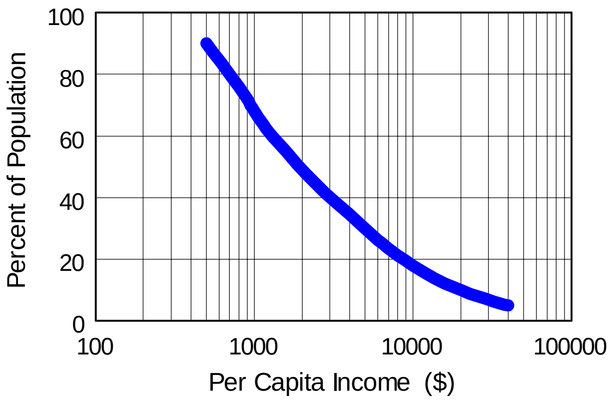

Figure 8. Lack of safe water and per capita income (per capita GDP). After Shafik, 1994, p.764.

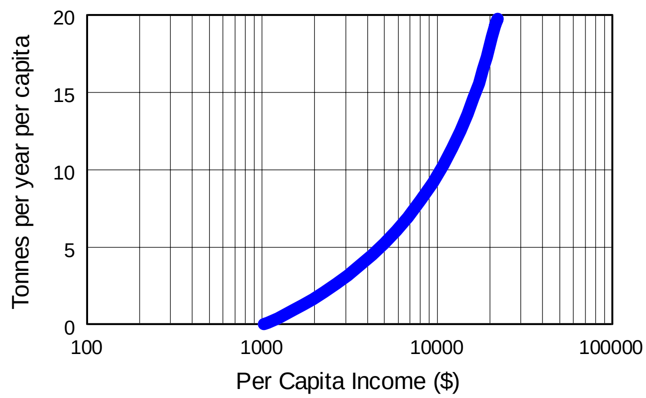

Figure 9. Carbon emissions per capita and per capita income (per capita GDP). After Shafik, 1994, p.764.

lead, sulfur dioxide, carbon monoxide, and
nitrogen dioxide on a county basis for the United States. Shafik (1994) developed curves for the following ten environmental parameters: lack of safe water, lack of urban sanitation, annual deforestation, total deforestation, dissolved oxygen in rivers, fecal coliform in rivers, suspended particulate matter, ambient sulfur dioxide, municipal solid waste per capita, and carbon emission per capita.

Environmental Kuznets curves commonly exhibit one of three shapes. The first represents an environmental benefit that increases continually with increasing per capita income, an example of which is lack of safe water (figure 8). In this case, Shafik (1994, p. 761) explains that the benefits to individuals are high (survival is at stake) and the costs of provision are fairly low. Figure 9 exhibits the second shape, showing a continuous increase with rising incomes. This example, carbon emissions per capita represents current practice and only reinforces the concerns as to fossil fuel combustion.

The Kuznets curve that has received the most interest and has elicited the most discussion has an inverted ‘U’ shape and it has been used to predict air quality as related to economic development (figure 10). The inverted ‘U’ shape indicates that outdoor air pollution, including sulfur dioxide and suspended particulate matter, increases in the early stages of a nation’s development, eventually reaches a maximum, and then declines as per capita income continues to increase. Similar shape curves have been reported for these two air pollution factors by three sets of researchers, although they reported different levels of income for the 'turning points'. Grossman (1995) calculated that the turning point for both factors was approximately $5000 (1985 US); Shafik (1994) placed the top of the curves between $3000 and $4000; and Selden and Song (1994) calculated much higher values, $8700 for sulfur dioxide and $10300 for suspended particulate matter.

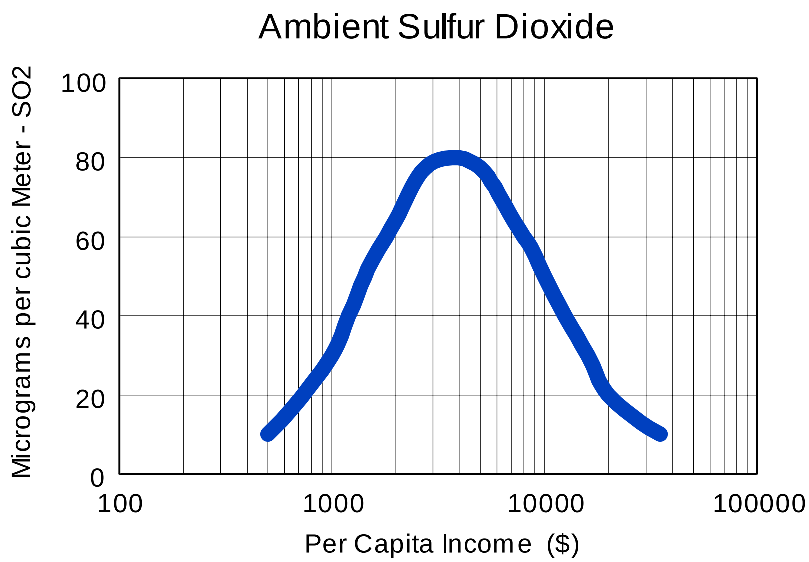

Figure 10. Ambient sulfur dioxide and per capita income (per capita GDP). After Shafik, 1994, p. 764.

The inverted 'U' shaped Kuznets curve could be interpreted to suggest that some environmental impacts of economic development are not serious because they will decline over time. Environmental degradation can be offset at a cost - scrubbers on power plants, for example - and increased per capita income gives nations the wealth with which to afford the cost. Technological developments and increase in the rate of technology transfer from the developed to the developing countries could accelerate the rate of improvement of environmental quality and allow for improvements in air quality to take place at lower per capita income levels than predicted from the historical data.

Not all economists are as sanguine about the concept of the Kuznets curves as the preceding paragraph might suggest. Stern and others (1996) summarized the current literature and critically reviewed the concept of the environmental Kuznets curve . Among the points they and others (Arrow and others, 1995) make is that the data are analyzed by country and do not take into consideration international trade and the possibility that wealthier countries are "exporting " their environmental problems to less developed countries. Criticism of the Kuznets curves is in how they are interpreted; their usefulness as a descriptive tool is generally accepted. Most recently, the entire May 1998 edition of "Ecological Economics", the journal of the International Society for Ecological economics, edited by Rothman and de Bruyn , was devoted to the environmental Kuznets curve. Six articles explored the structural factors (in economic terms) that might relate to the empirically observed relationships between income levels and measures of environmental impact. The authors of these articles generally conclude, from quite varied analyses, that the interpretation of the environmental Kuznets curve is more complicated than the simple observation that economic growth is good for the environment. Most of the previous researchers had also stated similar positions.

ALTERNATIVE ENERGY SOURCES

In an essay entitled "The Liberation of the Environment", Ausubel (1996) observed that there are two central tendencies that define the evolution of the energy system. One is rising efficiency and the other is that the system is freeing itself from carbon (see also Nakicenovic, 1996). For the past two hundred years the world has progressively undergone decarbonization as the most desirable fuels for energy generation evolved from wood to coal to oil and then to gas. The truly desirable element in these fuels is not the carbon they contain, but rather their hydrogen. The global rate of decarbonization, as measured by the amount of carbon per unit of primary energy produced, has decreased by 40 percent in the past century. Ausubel (1996) suggests that "...over the next century the human economy will squeeze most of the carbon out of its system and move, via natural gas, to a hydrogen economy." The displacement of carbon will be a huge environmental and economic challenge. Globally, the per capita use of carbon is 1000 kilograms per year(Ausubel.1996).

More than two thirds of the primary fuels currently consumed in the world is used to produce electricity, twice the share of 50 years ago. But, there are still two billion people in the world - one third of the population - without access to electricity (Ausubel, 1998). The installed electricity capacity of the world is predominantly thermal (coal, gas, and oil) with hydroelectric and nuclear power contributing significant amounts. Geothermal, wind, solar, biomass, photovoltaic and other renewable" sources make up less than one percent (figure 11). The United States leads the world in the use of renewables for generating electricity, comprising 80 percent of the world's total. Proponents of renewables for generating electricity take some encouragement from the double-digit growth in global shipments of photovoltaic cells (O'Meara,1997) and in a similar growth rate in global wind power generating capacity (Flavin, 1997). However, there will necessarily have to be much larger absolute increases in generating capacity from wind and solar before they have a significant impact on the world's totals. Currently, photovoltaics produce 0.02 percent of the world's electricity and wind produces 0.2 percent.

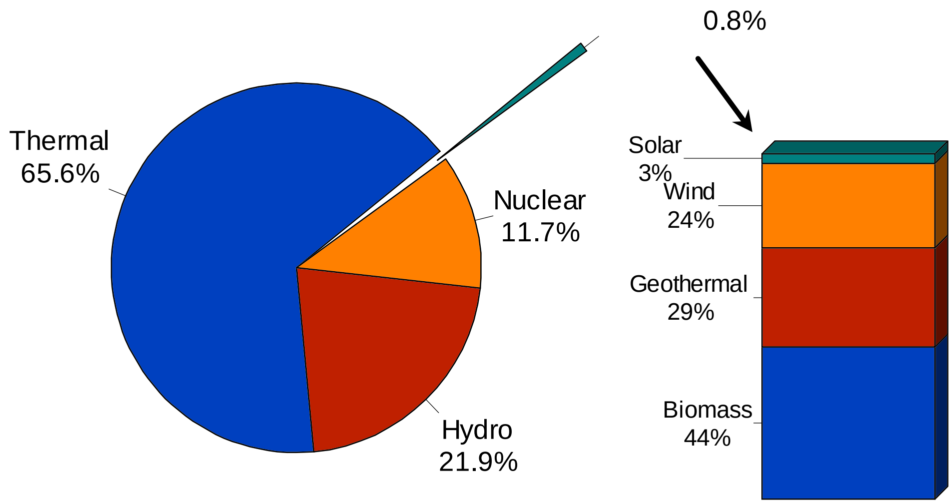

Figure 11. World electricity installed capacity and renewable energy sources used For generating electricity – 1996. From EIA, International Energy Annual, 1998, and Brown, and others, 1997.

CONCLUSION

The challenge is great and may not be met. However, technological changes can transform society in a matter of decades. Ausubel (1996) uses the example of the electric lamp, which was invented a little more than 100 years ago. The modern version of that lamp is 90 times as efficient as the original. Nuclear energy as a source of generating electricity did not exist half a century ago and now represents 12 percent of the world's installed capacity and accounts for 77 percent of the electricity produced in France. Looking ahead 50 years to the future is much more challenging than reviewing the past. But it is certainly not out of the realm of the plausible to imagine an energy regime that has not only evolved beyond fossil fuels but has done so before the current coal, oil, and gas resources are exhausted.

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